ICES WGPBI Report 2006

ICES Oceanography Committee
ICES CM 2006/OCC:07

Report of the Working Group on Modelling Physical Interactions (WGPBI)

6–7 April 2006

Nantes, France

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Recommended format for purposes of citation:

ICES. 2006. Report of the Working Group on Modelling Physical Interactions (WGPBI), 6–7 April 2006, Nantes, France. ICES CM 2006/OCC:07. 38 pp.

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Executive summary

Zooplankton provides the link between primary production and the fisheries. Modelling zooplankton is important to both those who need zooplankton as prey for fish models and those who need zooplankton as a predator (a closure term) in primary production models. The convergence of interest in these two modelling communities, which has become evident over the last few years, has the potential to improve modelling marine ecosystems from bacteria to fish.

The creation of a manual of 'Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History' will be overseen by WGPBI. This is the first step in the developed of a manual of 'Recommended Practices for Modelling Physical-Biological Interactions in Marine Ecosystem' which is a long term goal of WGPBI.

An investigation of operational and pre-operational applications of physical-biological models whose output is available over the internet revealed that while there are many web pages of physical operational models, there are relatively few examples of bio-physical coupled models and applications. As we expect the number of physical-biological applications to increase over the next few years, the survey will be repeated and expanded in two years.

Discussion of good ideas for embedding PBI in operational models led to the following conclusions: 1) ecosystem models based on first principles are beginning to supply new time-series of potential use for fisheries management, but improvements and more validation are needed; 2) there are many ideas for embedding PBI in operational models; and 3) moving the good ideas forward requires collaboration with operational groups to make it happen.

1 Opening of the meeting and adoption of the agenda

The meeting of the ICES Working Group on Modelling Physical-Biological Interactions (WGPBI) was held at the French Research Institute for Exploitation of the Sea (IFREMER) Center in Nantes, France from 6–7 April 2006. Our host was Pierre Petitgas, who was also the host and Co-Chair of the very successful workshop on “Advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions” (WKAMF) held at the same location on the previous three days.

The Working Group Chair, Charles Hannah, was unable to attend the meeting due to health problems and Mike St. John agreed to act as Chair for the meeting.

The Agenda (Annex 2) was adopted and then modified during the meeting to accommodate the needs of the discussions and people’s schedules.

The Terms of Reference for the meeting are given in Annex 3.

2 Presentation of New Results (ToR a)

The presentations opened with an invited talk by Geir Huse on ‘An adaptive IBM for *Calanus finmarchicus* in the Norwegian Sea.’ The invitation was extended because of the increased interest in zooplankton modelling within WGPBI and in the larger community.

Calanus *finmarchicus* is important across the North Atlantic because it serves as food for juvenile fish and for adult planktivorous fish. The goal of the work is to build an individual based model that can be used to investigate Calanus ecology in the Nordic Seas, can be used to provide prey fields for fish models, and can be used in 1D- and 3D-model configurations. A novel aspect of the work is that each individual carries both attribute information and strategy information. The attribute vector keeps track of the individual states and position, while the strategy vector contains "genes" that are inherited from parents to offspring and are used in generating life history strategies and behaviour. In particular vertical movements are calculated using a neural network from input information about the environment in combination with the "genes" (weights) coded on the strategy vector. Good strategy vectors, and thus behaviours, are found using a genetic algorithm by repeating simulations for hundreds of generations with repeated reproduction, mutation and selection. The strategy information is used as input to neural networks to translate the strategies into behaviour in the environment experienced by the IBM. The full model details are too extensive to report here. However the model inputs include temperature, currents, phytoplankton, light and predator distrubtions. A 100 year simulation of Calanus in the Nordic Seas shows encouraging spatial distributions. An important aspect of the presentation was a discussion of how it can be difficult to communicate IBM model details to the audience because of the rich detail in an IBM. A recent proposal by Grimm and Railsback (2005) holds some promise. This will be pursued at future WGPBI meetings.

Matteo Sinerchia spoke on ‘Testing theories in fisheries recruitment.’ He discussed the philosophy behind VEW and the recent developments. VEW is the Virtual Ecology Workbench (Woods 2005; Woods *et al.* 2005) which uses Lagrangian (particle) techniques to solve the dynamical equations. For a site near the Azores, the capabilities of the VEW were illustrated with results related to diatom photo-adaptation in the permanent thermocline and the dynamics of the deep chlorophyll maximum. In keeping with the zooplankton theme he also showed how the copepods develop two foraging modes: one with a diel migration and one focussed on the deep chlorophyll maximum. These two modes develop because surface diatoms are less abundant, but more nutritious.

Jorn Bruggeman talked on 'a biodiversity-inspired approach to marine ecosystem modelling'. His approach seeks to derive simple parameterizations for ecosystem dynamics by assuming an `infinite biodiversity' in which any hybrid between species may exist. He demonstrated this with a minimal model that is tentatively capable of representing a wide range of phytoplankton and bacteria species through variable investment in autotrophic and heterotrophic activity. This investment is implemented as partitioning of available biomass into three functions: light harvesting, structural biomass and organic matter harvesting. The associated partitioning coefficients quantify autotrophic and heterotrophic activity. By simultaneously allowing all possible combinations of (quantified) autotrophy and heterotrophy, and leaving selection of the most viable combinations to the environment, he obtained simple dynamics for an adapting, mixotrophic ecosystem. Presented with changing availability of light, nutrients and organic matter, the system varies smoothly between phototrophy and heterotrophy without requiring detailed information on hundreds of planktonic species. The model was shown to describe chlorophyll and nutrient observations at the BATS site well. This talk presented one example of a new generation of models that exploit the potential of non-mass state variables. A ToR to continue exploration of this new generation of models was generated.

Alexander Trofimov, who was unable to attend, sent a brief contribution on the ‘The influence of water dynamics on the distribution of 0-group herring in the Barents Sea’ (Annex 12). The results showed that in the Barents Sea, transport indices based on circulation model calculations can be used to provide useful predictions of 0-group herring abundance indices.

Elizabeth North gave an update on modelling oyster larvae dispersal in Chesapeake Bay. The overall research objective is to predict population dispersal of native and non-native oysters in Chesapeake Bay using hydrodynamic, particle-tracking, and adult demographic models. The presentation focused on preliminary results related to spatial patterns in oyster larvae settlement and on sensitivity studies related to particle dispersal. Spatial patterns in larval settlement differed between years, suggesting that changes in wind and river flow influence population dispersal. In addition, few particles (<2%) returned to bars from which they were released, indicating that the existence of multiple bars may be an important component of oyster population dynamics (i.e., no bar is an island). Sensitivity studies indicate that direction of transport and dispersal is affected by turbulence parameterizations. Vertical swimming behaviour can reduce dispersal and maintain patchiness by reducing the vertical spread of particles and thereby the effect of vertical shear on the patch. Vertical swimming speeds as low as 0.5 mm s^{-1} affected dispersal in stratified conditions. Orders of magnitude differences in horizontal variance measured *in situ* make validation from literature-derived values (e.g. Okubo log-log diffusion diagrams) fruitless. System specific validation studies will likely be required.

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3 Workshop on 'Advancements in modelling physical-biological interactions in fish early-life history (ToR b)

The "Workshop on advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions" (WKAMF) was held on 3–5 April, 2006 in Nantes France. It was chaired by E. North, A. Gallego and P. Pettigas. WKAMF was attended by 54 participants from 14 different countries. The workshop included two days of presentations, posters and structured discussions to survey recent advances in the field, develop a list of recommended practices, and identify research needs. The final day of the workshop focused on writing sessions devoted to developing teams for international collaborative proposals and a manual of best practices. The details of the workshop and recommendations will be reported in the separate workshop report.

The workshop participants agreed to develop of a "Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History". Workshop participants formed four teams to coordinate manual development: particle tracking (led by David Brickman), connectivity (led by Claire Paris), recruitment prediction (led by Sarah Hinckley), and adaptive sampling (led by Pierre Pepin). The workshop Co-Chairs will coordinate the overall development of the manual. The final draft will be submitted to WGPBI and WGRP members one month prior to the 2007 WGPBI meeting to allow for review and discussion at the meeting. A decision will be made at the 2007 WGPBI meeting regarding the appropriate means of dissemination, potentially as an *ICES Cooperative Research Report.* For WGPBI this activity represents the first step in the development of such a manual for the broader PBI field.

Workshop results will also be dissemination through other mechanisms:

1) Joint submission of manuscripts to *Marine-Ecology-Progress-Series*. Nineteen manuscripts based on oral and poster contributions are planned for submission. Dr Howard Browman has agreed to facilitate and oversee publication of manuscripts from the workshop in MEPS. Workshop Co-Chairs will serve as guest editors and contribute an overview article. Intended manuscript submission deadline is 1 July 2006.

2) The development of international collaborative proposals. Forming cross-disciplinary multi-national research teams was deemed an important step for addressing the research priorities that were identified during the workshop, a definitive action to advance the field. At least four teams of 3–6 researchers were formed and plan to submit proposals to national funding agencies within the next 12–18 months.

3) A workshop website. Co-Chair Elisabeth North agreed to maintain the workshop website and transform it into a means for workshop participants to share reports, model test cases, open-source code, and announcements. The address is http://northweb.hpl.umces.edu/wkamf/home.htm

Two ToRs were generated for the next meeting.

4 Identify good ideas for embedding PBI in operational models (ToR c)

The discussion on this ToR was led by Einar Svendsen. He opened with a presentation showing several applications where physical-biological interactions are embedded in the Norwegian operational models. These include showing an inverse relationship between simulated ocean transport into the Barents Sea and observed cod recruitment; the beginning of a relationship between simulated annual primary productivity and cod recruitment three years later; and simulating harmful algal blooms.

His conclusions were:

- Ecosystem models based on first principles are beginning to supply new time-series of potential use for fisheries management, but improvements and more validation are needed.
- An important area for improvement is zooplankton modelling as one needs to model the zooplankton in order to simulate the linkages between primary production and fish (larvae and juveniles).
- The results showing linkages between cod recruitment and the primary production, inflow and ocean temperature suggest that progress is possible on the cod recruitment problem.

There was active discussion on this topic and good use was made of the material presented on the inventory of operational and pre-operational coupled bio-physical models (ToR d, which was discussed immediately before this item). Notes on the discussion are included in Annex 11.

Three further points:

- WGPBI can make proposals for embedding PBI in operational models, however to there needs to be collaboration with operational groups to make it happen.
- The discussion at WGPBI tends to focus on ‘ecosystem models based on first principles’ as that is the area of interest of the members. However useful operational models can be built around models based on correlations and observations that a particular organism often appears when certain conditions are achieved; e.g. the sea nettle prediction system in Chesapeake Bay (USA; coastwatch.noaa.gov/seanettles). For many operational purposes, this second type of model is readily implemented and at least as useful as one based on first principals.
- The ICES ASC Theme Session on ‘Operational Oceanography’ will be another forum for discussion of this issue.

On the basis of the discussion, a recommendation and two possible ToRs were formulated. The following ToRs will be considered for inclusion in the workplan for 2007: Continue to investigate (pre)operational applications of PBI models with special focus on the availability of its products; and Review, by using recent inventories, the access to operationally produced data that may be used for the development and validation of PBI models.

Recommendation

Based on the outcome of ToR c) the WG on Modelling Physical and Biological Interaction, WGPBI, recommends that a separate ICES working group on operational oceanography be created to work on model products and model generated indicators.

The WGPBI recommends further that this be discussed intersessionally with the ICES-IOC Steering Group on GOOS and the ICES-EuroGOOS Planning Group on the North Sea Pilot Project in order to include also the tasks of these groups into the new working group.

Justification:

The challenging tasks of WGBPI requires mostly active scientist while operational oceanography has to be implemented and maintained by operational people.

GOOS, Coastal GOOS and regional operational oceanographic systems are now being implemented at all scales. The ICES advisory system will be depending on the products and services of these systems. An ICES working group on operational oceanography can formulate the ICES requirements, plan the production and also co-ordinate an ICES contribution to GOOS.

5 Investigate current pre-operational applications of PBI models (ToR d)

An inventory of operational and pre-operational marine and estuarine 3D hydrodynamic and coupled bio-physical models was carried out by Stephan Dick, Elizabeth North, Morten Skogen and Trisha Amundrud. S. Dick presented examples of different PBI models with applications on the internet including short descriptions of programs, models, available output as well as information on model developers, funding and web URLs. An important criterion for the selection of models was that hindcast, nowcast and/or forecast data should be available on the internet. The compiled inventory is far from being complete, for example several groups have not been surveyed yet, and the survey was only carried out for Europe and the USA. In total, 40 web URLs had been compiled mostly presenting results of physical models. A webpage with the URL links was developed to help communicate survey results to the ICES community. It is entitled “WGPBI Inventory of Operational and Preoperational Models” (http://northweb.hpl.umces.edu/WGPBI/WGPBI_links.htm).

The complete report is contained in Annex 10 and has examples of coupled physical-biological models and applications. The report is summarized as follows. Many web pages of physical operational models and applications could be found on the internet. However, there exist relatively few examples of bio-physical coupled models and applications. A few examples present synthesis of in-situ measurements, remote sensing and forecast data. Most PBI web pages show model results for lower trophic levels. The typical model output consists of (near) real time maps of physical parameters together with nutrients and phytoplankton (chlorophyll) distribution. A few models show applications for certain species (*Chrysaora quinquecirrha, Karlodinium micrum ...).* In some countries operational biochemical models are being developed at the moment.

It is recommended that WGPBI repeat the survey of operational and pre-operational PBI models and their applications within two years in order to update the description of available models and products and to investigate the progress in development of operational PBI models. Also, it is recommended that the “WGPBI Inventory of Operational and Preoperational Models” webpage be linked to the WGPBI webpage.

6 Complete the compilation of data sets suitable for testing 1D ecosystem models (ToR e)

The Numerical Experimentation Subgroup (NESG) had its first meeting immediately before the WG meeting in 2005. The goal of the group was to define and carry out numerical experiments that would provide insight into important issues in modelling physical-biological interactions. One of the short term goals was to compile data sets suitable for testing 1d ecosystem models. The last year was not a good one for NESG; the group leader stepped down and the annual group meeting was cancelled when WGPBI chair C. Hannah was unable to attend the WG meeting and chair the NESG meeting. As a result there was no progress on this ToR.

Members of WGPBI will attempt to resurrect NESG because testing of 1D models is an important tool for improving the PBI models. We note that the overall goals of the group are shared by at least two other groups

1) Dynamic Green Ocean Project (Le Quere *et al*. 2005 and lgmacweb.env.uea.ac.uk/green_ocean/index.shtml).
2) US JGOFS synthesis and modelling project (www1.whoi.edu/mzweb/syn-mod.htm).

One of the unique aspects of NESG is that it has access to 1D models based on two very different numerical integration schemes (Eulerian and Lagrangian). This would have allowed comparisons that other groups would not be able to do.

This ToR will be put aside for the time being. It may be reintroduced when NESG is up and running.

Reference

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7 Review maximum phytoplankton growth rates as function of temperature (ToR f)

The original questions that gave rise to this ToR were 'Does temperature limit the maximum growth rate of the community?' or 'Is there always a species that can grow rapidly at the given temperature so that community primary production is roughly independent of temperature?' Mike St. John talked about the current status of a literature review to address these questions.

In a review of batch culture data, Eppley (1972) found that a reasonable upper bound on the growth rates as a function temperature was provided by a curve with a Q10 of 1.8 (the growth rate increased by a factor of 1.8 for a 10ºC increase in temperature. This was valid over a range of about 0 to 30ºC. There is a growing recognition that the Epply curve does not adequately represent the maximum growth of a community. For example the growth rates of ice algae measured by Michel *et al.* (1989) at 0ºC are comparable to the growth rates of diatoms at 20ºC and the review of Brush *et al.* (2002) finds examples in literaturee for growth rates that exceed the Eppley curve.

Many ecosystem models use the Eppley (1972) curve to prescribe the maximum growth rate and then reduce the maximum growth rate by factors that prevent the phytoplankton from realizing this hypothetical maximum rate. The limiting factors a generally day length, light levels and nutrient concentrations. A schematic version of these relationships is

$$G = G_{\max} \cdot f \cdot \mathrm{LTLIM} \cdot \mathrm{NUTLIM} \qquad (1)$$

where

- where G is the realized daily growth rate (d^{-1}) (base e);
- f is the fraction of the day during which there is light;
- LTLIM and NUTLIM are dimensionless ratios from 0 to 1 which describe light and nutrient limitation of growth, respectively.

There are problems with this approach beyond the limitations of using the Eppley curve. Brush *et al.* (2002) argue that that simply raising the Eppley curve to match some of the more recent data while keeping Q10 constant does not solve the problem. They argue that while models based on the Eppley curve can simulate the plankton biomass they tend to underestimate the primary production and therefore they must be systematically underestimating the grazing and mortality.

Cole and Cloern (1987) suggest an alternative approach to estimating primary production in regions where there is no nutrient limitation. They demonstrated a strong (r^2 = 0.82) linear relationship between daily photic zone productivity (P_d, mgC m^{-2} d^{-1}) measured using ^{14}C and the parameter BZ_pI_0, where

B = phytoplankton biomass measured as chl *a* (mg m^{-3}),

Z_p = depth of the photic zone (m) (defined as the depth of the 1% light level), and

I_0 = surface irradiance (photosynthetically active radiation, PAR) (E m^{-2} d^{-1}).

Their function was:

$$P_d = 150 + 0.73(BZ_pI_0)$$

This approach consistently explain the majority of the variation in production data they reviewed, and with few exceptions the slopes were remarkably consistent among the regressions.

Other interesting notes:

- Some ecosystem models make the phytoplankton growth rate a function of light and nutrients only and are independent of temperature (e.g. Evans and Parslow 1985, Fasham *et al.* 1990).
- In a field study, Cote and Platt (1983) found that the Eppley curve provided a useful upper bound on the observed growth rates (as a function of temperature) but temperature variations only explained 4% of the day to day variations in the growth rates.
- The laboratory study of Goldman (1977) suggests that biomass accumulation is roughly independent of temperature.

As a final point, Raven and Geider (1988) argue that the basic formulation of (1) is incorrect because the response to temperature changes depends on the light and nutrient status of the cells. Therefore the growth rate cannot be written as

$$G(T,N,L) = A(T)\ B(N)\ C(L)$$

because the separation of variables is wrong. The simplest formulation must be

$$G(T,N,L) = D(T,N)\ E(T,L)$$

where T,N,L represent temperature, nutrients and light respectively.

At this point in the review, the net effect of temperature on a community property like primary productivity is not clear. We leave the last words to Joel Goldman (1977):

> The direct influence of temperature on phytoplankton division rates is clear: within defined temperature limits division rates increase with increasing temperature (Eppley 1972; Goldman and Carpenter 1974). Yet, as discussed in detail by Eppley (1972), a number of species increase in biomass as temperature is lowered, Jørgensen (1968) first observed this phenomenon; in Skeletonema costatum lowered temperatures led to lowered division rates but to higher rates of carbon and nitrogen assimilation. Increased enzyme production as a result of a higher cellular protein concentration was suggested as an adaptive mechanism for maintaining high photosynthetic rates at the lower temperatures.

The discussion on this item was lively because while most agree that temperature affects which species are present, there is no consensus on the effects of temperature on primary productivity. This discussion was the impetus for the recommendation that 'WGPBI would benefit from having some plankton specialists.'

A ToR was generated to complete the review.

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8 Cooperate with SGBEM to explore ecosystem models (ToR g)

Wolfgang Fennel (chair of SGBEM) made a brief presentation on the work of the Study Group on Baltic Ecosystem model issues status of SGBEM. The group's vision is that since the Baltic Sea is one of the most intensely observed seas it should also become one of the best modelled systems.

W. Fennel posed the following question (and challenge). Given that 3D simulations of the Baltic Sea response to nutrient loading scenarios have become an important tool for environmental assessment, are the 3D models sufficiently mature that they could be used to assess the response of the Baltic system to different levels of fishing effort?

SGBEM has suffered from the common problems of having different participates at different meetings, a low commitment regarding inter-sessional work, and low participation from western countries.

This ToR is complete; the final meeting of SGBEM is later in April in Helsinki, Finland.

9 Collaborate with WGRP to enhance the use of physical-biological models for prediction of fisheries recruitment (ToR h)

There is active collaboration between WGPBI and WGRP. The workshop on “Workshop on advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions” (WKAMF; ToR b) was a joint effort. The workshop participants have agreed to develop a “Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History”. This will be a joint project of WGPBI and WGRP. It is also expected that some joint research projects will arise from discussions at the workshop.

WGPBI also collaborated with SGRESP (Regional Scale Ecology of Small Pelagics) on a workshop on Indices of Meso-scale Structures in ICES waters (WKIMS; co-chaired by B. Planque and C. Schrum). The workshop results will be described in a separate report. In summary WKIMS was successful in setting up procedures to extract meso-scale features such as fronts and eddies from satellite images and hydrodynamic models. It made first attempts to produce maps of activity in these features. The participants recognised the importance of the step made as well as the work still ahead to define and estimate indices. The group is interested in further development in meso-scale indices of oceanographic features to couple such data with fish spatial distributions.

The WKIMS participants recommended that Terms of References be defined by WGPBI for guiding further developments on this theme which is of interest to SGRESP and the LRC committee. The proposed terms of reference to WGPBI could be: Review progress in the estimation of meso-scale indices of oceanographic features and evaluate the reliability of the indices for their use in explaining fish distribution patterns. Including this ToR awaits a volunteer to pursue the work.

There was active discussion of the work done by WKIMS in response to this presentation by Pierre Petitgas. The conclusion was that the proponents of WKIMS are welcome to continue their work on meso-scale features as part of WGPBI. An ICES ASC theme session proposal was drafted (Annex 9).

10 Progress in Zooplankton Modelling gained in the German GLOBEC Project

There is renewed interest in zooplankton modelling in the community at large and within WGPBI. The invitation to Geir Huse to speak at the opening of the meeting was the result of this interest. The WG also asked Thomas Neumann and Andreas Moll to report on the progress in zooplankton modelling within German GLOBEC. Wolfgang Fennel made the presentation on their behalf. His talk focussed on the modelling techniques being developed to improve the zooplankton models, such as resolving the developmental stages of some species and adding vertical behaviour to a concentration based model formulation. The written report follows.

Report on zooplankton modelling in German GLOBEC

(Thomas Neumann and Andreas Moll)

The German GLOBEC project is an interdisciplinary approach to investigate the bottom-up cause-effect chain affecting recruitment success of fish. Regionally the study is focused on two target systems, the Baltic and the North Sea. Detailed information on the project is available from http://www.globec-germany.de/. One aspect of the project is modelling the ecosystem from physics up to the prey fields for fish larvae which includes zooplankton.

For the Baltic Sea a stage structured copepods model was developed and coupled to a 3D ecosystem model ([1]). The basic copepods model resolves 4 development stages. Each stage is represented by biomass and abundance. The individual mass (biomass over abundance) controls the moulting process of copepods stages ([2]). The copepods model comprises two model species. Each species displays a different physiology, behaviour and life cycle ([3]). Model specie one lives in the upper part of the water column and is guided by Baltic Sea species *Acartia spp.* and *Temora spp*. The second model species represents *Pseudocalanus spp*. which lives in deeper parts of the water column near the halocline. Model species one over-winter as dormant eggs as well as adult stages while model species two (*Pseudocalanus*) over-winter in the last copepodite stage. Hatching of dormant eggs is controlled by oxygen and temperature and triggered due to an endogenous clock. With the model system a period from 2000–2005 was simulated. The current stage of model development is the comparison with observations and refinement of parameterization.

For the North Sea as a starting point in modelling the status of three-dimensional ecosystem model validation including zooplankton biomasses was reported ([4]). Currently only a few space resolved models include zooplankton in terms of biomass or as a structured population. Following the approach in the GLOBEC Germany project we used the basic copepod model as developed in the Baltic Sea and started zooplankton population modelling, but in contrast to the Baltic, for *Pseudocalanus elongatus* due to the fact that this species is wide-spread and stated one of the most abundant copepod species related in the North Sea area. First modelling effort was, the parameterisation of the structured zooplankton population model in a zero-dimensional version particularly with regard to physiological behaviour to get realistic characteristics of growth and development under conditions of temperature and food ([5]). Second, this population model was integrated into the complex marine ecosystem model ECOHAM2 with 13 state variables resolving the carbon and nutrient cycle to study annual cycles under realistic weather and hydrographic conditions applied to a water column. The vertical profiles of selected state variables were compared to the physical forcing to study differences between zooplankton as one biomass state variable or partitioned into five population state variables. Simulated generation times as affected by temperature and food depict up to six generations within the annual cycle ([6]). Quite a number of key species exist for the North Sea and in contrast to the Baltic Sea modelling with two different classes of key species. Therefore, as a third step, we started to implement the *Pseudocalanus elongatus* population in competition to the rest of the bulk zooplankton. This is ongoing and the next step is to compare this simulation with observations for biomass and abundance in the North Sea. At this time, three-dimensional zooplankton fields in terms of biomass and abundances were simulated for several different years (1986, 1993–1996, and 2000–2003) and will be analysed to investigate the bottom-up approach in affecting recruitment success of larvae fish for GLOBEC cruises.

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[6] Moll, A., and Stegert, C. 2006. Modelling Pseudocalanus elongatus population dynamics embedded in a water column ecosystem model for the northern North Sea. Journal of Marine Systems, (special issue AMEMR Conference, re-submitted).

11 Other Business

- An important issue that arose in the general discussion was that it would be good to have some plankton specialists joining the group "to keep the modellers on the right track". Names that came up were P.Gentien, L.Naustvoll, and J.Adolff. Einar Svendsen will contact Lars Naustvoll.
- Hydrodynamic models can contribute to understanding ecosystems in more ways than just providing advection and mixing for plankton models. The hydrodynamic fields can be combined with other ecological knowledge to make predictions about aspects of the ecosystem. One example is the sea nettle prediction project in Chesapeake Bay (USA) discussed in reference to ToR d. In this operational program (coastwatch.noaa.gov/seanettles) maps of probable sea nettle presence are created by identifying locations where the current environmental conditions are favourable to sea nettles. This is accomplished using data derived from hydrodynamic computer models and NOAA satellites. A second example is the benthic habitat mapping project presented by Charles Hannah last year where observations and model output were used as input to a habitat template to integrate multiple environmental fields into a single habitat map. There are probably several more examples. The following ToR was discussed and postponed for at least 1 year ‘Review the state of the art with respect to the use of hydrodynamic models to predict optimal habitats.’
- There were no volunteers with a burning desire to organize a workshop for 2008.
- Several draft proposals for ICES ASC theme sessions for 2007 or 2008 are given in Annex 9
- The working group was required to nominate a new chair as 2006 is the final year of Dr Hannah’s current term. The group nominated two co-chairs: Dr Charles Hannah (Canada) and Dr Uffe Thygesen (Denmark). This item is included in the recommendations.
- The next meeting will be held in late March 2007 hosted by the Institute of Marine Research in Bergen Norway.
- The resolution for the next meeting can be found in Annex 4.
- The working group thanks Pierre Petitgas and staff at IFREMER for their excellent job in hosting both WKAMF and WGPBI.
- Charles Hannah thanks Mike St. John for agreeing act as chair for the meeting.
- The Chair thanks Elizabeth North, Alejandro Gallego, and Pierre Petitgas for organizing WKAMF and for their willingness to follow through on the manual of best practise.

Annex 1: List of participants

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Annex 2: Draft Agenda

Thursday morning (0900 – 1230) 6 April 2006

Welcome, Introductions, Logistics (acting chair)

Geir Huise (invited talk on modelling zooplankton) Time 30-40 minutes

New results (5 x 20 minutes)

- **Elizabeth North** – Modelling Oyster Larvae in Chesapeake Bay
- **Matteo Sinerchia –** thesis work
- **Matteo Sinerchia –** the status of the Virtual Ecology Workbench
- **Jorn Bruggeman** - Biodiversity-inspired approach to marine ecosystem modelling'
- **Einar Svendsen** - New results from Norwegian model.

ToR d) Investigate current pre-operational applications of PBI models. Presentation by **Stephan Dick** and others. 1 hour

ToR c) Identify good ideas for embedding PBI in operational models (e.g., MERSEA) to generate the first generation of products. Presentation and discussion led by **Einar Svendsen**. This will include discussion on how to make modelled PBI products (and derived indicators) operationally available for the ICES community? 1 hour. This item needs a rapporteur. The notes will be basis for item in WG report. This will spill into afternoon

Thursday afternoon (1400 – 1800)

Finish ToR C.

ToR b) plan and execute the workshop on 'Advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions' and report on conclusions;

Report from WKAMF: **North, Gallego, and Petitgas**

ToR h) collaborate with WGRP to enhance the use of physical-biological models for prediction of fisheries recruitment. **North, Miller**, et al. WKAMF and collaborations that result.

Report from WKIMS. **Pierre Petitgas**

Discussion

- Announce WGPBI sponsored Theme Sessions for 2006
- Ideas for theme sessions in 2007. Need a PBI session. Hannah willing to co-convene
- Workshop ideas for 2008. Any volunteers?
- Reminder that need to nominate a chair (or co-chairs) or 2007-2010.

Friday morning (0900 – 1230)

Report on zooplankton modelling in German GLOBEC. A written contribution from Neumann and Moll.

ToR f) Review maximum phytoplankton growth rates as function of temperature as the first step in understanding whether temperature regulates total production when integrated across the entire phytoplankton community. Brief report by **St. John**. 30 minutes.

ToR g) cooperate with SGBEM to explore ecosystem models.
Brief report by **Wolfgang Fennel**

Review of action items for 2005. Acting Chair

Draft proposals for ICES ASC theme sessions in 2007.

Draft resolutions for 2008 workshops.

Friday afternoon (1400 - 1600)

Draft WGPBI Resolution for 2007

- Terms of Reference
- Location and local host for 2007 meeting (Dates can be set later).

Add items to the WGPBI Activity list

Ideas for invited speaker next year

Announce WGPBI sponsored Theme Sessions for 2006

Outline writing assignments for Working Group Report

Action Items for 2006 – who is actually doing things?

Nominate a new Chair (or Co-Chairs) for 2007–2010.

Close the meeting

Annex 3: WGPBI Terms of Reference 2005

The Working Group on Modelling Physical/Biological Interactions [WGPBI] (Chair: C. Hannah, Canada) will meet in Nantes, France from 6–7 April 2006 to:

a) Present and discuss new results related to developments and validation in modelling PBI;

b) Plan and execute the workshop on ‘Advancements in modelling physical-biological interactions in fish early-life history: recommended practices and future directions’ and report on conclusions;

c) Identify good ideas for embedding PBI in operational models (e.g., MERSEA) to generate the first generation of products;

d) Investigate current pre-operational applications of PBI models;

e) Complete the compilation of data sets suitable for testing 1D ecosystem models;

f) Review maximum phytoplankton growth rates as function of temperature as the first in understanding whether temperature regulates total production when integrated across the entire phytoplankton community;

g) Cooperate with SGBEM to explore ecosystem models;

h) Collaborate with WGRP to enhance the use of physical-biological models for prediction of fisheries recruitment.

WGPBI will report by 7 May 2006 for the attention of the Oceanography Committee.

Annex 4: Proposed Terms of Reference 2006

The **Working Group on Modelling Physical Biological Interactions** [WGPBI] (Co-chair: C. Hannah, Canada and U. Thygesen, Denmark) will meet in Bergen, Norway from [date to be decided] March 2007 to:

a) Present and discuss new results concerning physical-biological interactions;

b) Complete the publication of papers from WKAMF;

c) Complete the draft of the Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History;

d) Review existing operational data flow from sustainable observational and modelling systems such as GOOS and report on activities relevant for the work of WGPBI;

e) Report on promising alternative approaches for ecosystem modelling;

f) Assess the state of the art in the study of small scale feeding processes (with particular reference to zooplankton and fish larvae) and make recommendations for model parameterisation;

g) Complete the review of maximum phytoplankton growth rates and primary production as function of temperature;

h) Collaborate with WGRP to enhance the use of physical-biological models for prediction of fisheries recruitment;

WGPBI will report by [date to be decided] to the attention of the Oceanography Committee.

Supporting Information

PRIORITY:	The WG should be given high priority, since it is concerned with the evaluation and development of the modelling tools used to increase the understanding of the interaction between the living resources in the sea and its ambient physical and abiotic environment. This understanding is essential to the successful development of predictive capability of the state and evolution of the ecosystem for issues such as harmful algal booms, eutrophication, marine protected areas, fish recruitment, and global change. This contributes directly to fulfilling the vision of ICES, "to improve the scientific capacity to give advice on the human impact on, and impacted by, marine ecosystems.".
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	The work of WGPBI contributes to the following ICES Activities: Action Plan no. 1.5 (modelling biological-physical interactions in the sea), Action Plan no 1.1 (provide feedback about research needs), Action Plan no 1.2 (increase knowledge with respect to functioning of the ecosystem). Contributions towards other Activities are noted in the justification below. **a)** Providing a forum for the presentation and discussion of new results is an important component of the Group's mandate. **b)** Nineteen manuscripts based on oral and poster contributions at the recent workshop on 'Advancements in Modelling Physical-Biological Interactions in Fish Early-Life History: Recommended Practices and Future Directions' (WKAMF) are planned for submission to *Marine Ecology Progress Series*. Workshop co-chairs will serve as guest editors and contribute an overview article.

Scientific justification and relation to action plan: (continued)	**c)** The participants at WKAMF agreed to develop a "Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History". They formed four teams to coordinate manual development on four themes: particle tracking, connectivity, recruitment prediction, and adaptive sampling. The workshop co-chairs will coordinate the overall development of the manual. The final draft will be submitted to WGPBI and WGRP members one month prior to the 2007 WGPBI meeting to allow for review and discussion at the meeting. A decision will be made at the 2007 WGPBI meeting regarding the appropriate means of dissemination, potentially as an ICES Cooperative Research Report. For WGPBI this activity represents the first step in the development of such a manual for the broader PBI field. **d)** For WGPBI to contribute to embedding useful PBI modules into operational models, the WG needs a greater understanding of the current generation of operational models. **e)** Unifying biological principles, such as thermodynamic considerations and body size scaling, offer the potential to derive ecosystem models for plankton dynamics that are in some sense unified models for wide ranges of marine species. One motivation for these new approaches is that traditional ecosystem models are based on extensions of single species models and require detailed quantitative knowledge of all relevant species. The process seems endless as ecologists and physiologists uncover relevant species and processes at rates that far exceed those at which high-quality quantitative knowledge on species becomes available. The WG will devote ½ day to a discussion of the strengths and weaknesses of alternative approaches to ecosystem modelling with a focus on the capability to generate reliable quantitative predictions of biological variables. **f)** The need for improved models of zooplankton has been identified as the key to linking primary production to larval fish in ecosystem models based on first principles. As such there is a need to assess the state of the art in the study of small scale feeding processes (with particular reference to zooplankton and fish larvae) and make recommendations for model parameterisation. **g)** It is well known that for each species of phytoplankton, the maximum growth rate is a function of temperature. The question is 'Does temperature limit the maximum growth rate of the community?' or 'Is there always a species that can grow rapidly at the given temperature so that primary production is roughly independent of temperature?' This has important implications for modelling and our current techniques for assessing the response of an ecosystem to temperature changes. **h)** Members of WGPBI and WGRP (Working Group on Recruitment Processes) share the common goal of enhancing, guiding, and promoting use of coupled physical-biological models for prediction of fisheries recruitment. Close coordination between Working Groups is required to prevent duplication of efforts. WGPBI members will continue to work together on the activities that follow from WKAMF.
Resource requirements:	None
Participants:	The Group is normally attended by some 20–30 members and guests. The Working Group benefits from the participation of those outside of the modelling community. Observational and experimental scientists with an interest in physical-biological interactions are encouraged to attend.
Secretariat facilities:	None.
Financial:	No financial implications.
Linkages to advisory committees:	ACFM, ACE
Linkages to other committees or groups:	ICES-IOC Working Group on Harmful Algal Bloom Dynamics, WGRP, BSRP, SGRESP
Linkages to other organizations:	The work of this group is closely aligned with similar work in GEOHAB (IOC/SCOR), GLOBEC (IOC/SCOR), IMBER and PICES.
Secretariat marginal cost share:	None

Annex 5: Recommendations

Recommendation		Action
1.	WGPBI nominates Dr Charles Hannah (Canada) and Dr Uffe Thygesen (Denmark) as co-chairs.	ICES Oceanography Committee
2.	Develop a GOOS WG and WGPBI strategy. A possible mechanism is given next.	ICES Oceanography Committee H. Dahlin and E. Svendsen
3.	Based on the outcome of ToR c) the WG on Modelling Physical and Biological Interaction, WGPBI, recommends that a separate ICES working group on operational oceanography be created to work on model products and model generated indicators. The WGPBI recommends further that this be discussed intersessionally with the ICES-IOC Steering Group on GOOS and the ICES-EuroGOOS Planning Group on the North Sea Pilot Project in order to include also the tasks of these groups into the new working group. Justification: The challenging tasks of WGBPI requires mostly active scientist while operational oceanography has to be implemented and maintained by operational people. GOOS, Coastal GOOS and regional operational oceanographic systems are now being implemented at all scales. The ICES advisory system will be depending on the products and services of these systems. An ICES working group on operational oceanography can formulate the ICES requirements, plan the production and also co-ordinate an ICES contribution to GOOS.	ICES Oceanography Committee H. Dahlin and E. Svendsen
3.	WGPBI would benefit from having some plankton specialists join the group "to keep the modellers on the right track". Of particular interest is improved parameterizations related to modelling primary production.	Oceanography Committee and WGPBI.
4.	WGPBI should oversee the creation of a manual of 'Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History' by the participants in WKAMF.	Oceanography Committee and WGPBI
5.	WGPBI should continue to report on promising alternatives approaches to ecosystem modelling.	Oceanography Committee and WGPBI
6.	In two years WGPBI should repeat its survey of operational and pre-operational applications of physical-biological models whose output is available over the internet.	

Annex 6: Action Items 2005/2006

Item 1: Osborn will co-convene a theme session in 2005 on ‘Recent advances in our understanding of marine turbulence.’ (jointly with WGOH). Cancelled due to lack of papers.

Item 2: North, St. John and Gallego will convene a theme session in 2005 on ‘Connecting Physical-Biological Interactions to Recruitment Variability, Ecosystem Dynamics, and the Management of Exploited Stocks’ (Jointly with WGRP). This was very successful with 45 submitted papers. In addition session presenters won 2 awards: Ute Hochbaum for Best Newcomer and Beth Scott for Best Paper.

Item 3: Peters and Hannah will complete the special issue of the J. of Marine Systems based on the WKFDPBI. Done. Peters and Hannah (2006).

Item 4: North, Gallego, and Petitgas will host a workshop on ‘Advancements in modelling physical-biological interactions in the early-life history of fish: recommended practices and future directions larval fish modelling.’ WKAMF Done. More action items generated.

Item 5: Stipa will co-convene a theme session at the ICES ASC in 2006 on ‘Harmful Algae Bloom Dynamics; Validation of model predictions (possibilities and limitations) and status on coupled physical-biological process knowledge’ (Joint with WGHABD). In progress.

Item 6: Svendsen and Han will write a resolution for a theme session at the ICES ASC 2006 on ‘Operational Oceanography.’ Done.

Item 7: Schrum will collaborate with Planque and Petitgas of SGRESP (Study Group on Regional Scale Ecology of Small Pelagics) on a workshop to construct long term series of meso-scale features from hydrodynamic model outputs. WKIMS Done.

Item 8: St. John will review and report on the temperature-dependence of maximum growth rates for phytoplankton and report at the WGPBI 2006. In progress.

Item 9: Neumann and Moll will draft a synthesis of progress on zooplankton modelling in German GLOBEC and report at the WGPBI 2006. Done and included in this report

Item 10: Skogen will invite Geir Huse (Norway, and a member of WGPBI) to give talk at WGPBI 2006 on zooplankton IBMs. Geir will speak at WG meeting 2006.

Item 11: Members of the Numerical Experimentation Subgroup will complete the compilation of data sets suitable for testing 1D ecosystem models. Not much progress.

Item 12: Skogen, North, Dick and Amundrud will investigate current pre-operational applications of PBI models and report at the WGPBI 2006. Reported at meeting and report is included.

Item 13: Svendsen, Han, Amundrud and Dick will identify good ideas for embedding PBI in operational models (e.g., MERSEA) to generate the first generation of products and report at the WGPBI 2006. Report at meeting.

Item 14: Skogen will continue to encourage members of WGPBI to learn to tell jokes. In progress.

Item 15: Skogen and Moll will submit for publication their model comparison and Moll will submit for publication the comparison of the 3D ecosystem models of the North Sea (co-authored with G. Radach). Done. Skogen and Moll (2005) and Radach and Moll (2006).

Item 16: Hannah to ask Vezina to give a talk on applications of macroecology to testing models. Vezina not available. Postponed

Item 17: St. John and Hannah will work towards a joint EuroOceans and ICES workshop on parameterizing ecosystem models that could take place immediately before WGPBI 2007. This is in progress for March 2007 in Cadiz. It will not be an official ICES event.

Item 18: Vezina, Hannah, and St. John will write a short project description related to zooplankton grazing models. This could be the basis for PhD project under EuroOceans. This did not work out.

Item 19: Hannah will invite Marjorie Friedrichs (US JGOFS Regional Ecosystem Modelling Testbed Project) to the next NESG meeting. This did not work out. Perhaps next time.

References

Peters, F., and Hannah, C.G. (editors). 2006. Special Issue on Future Directions in Modelling Physical-Biological Interactions. J. Marine Systems. In press.

Radach, G., and Moll, A. 2006. Review of three-dimensional ecological modelling related to the North Sea shelf system - Part 2: Model validation and data needs. Oceanography and Marine Biology; an Annual Review, Vol. 44:in press.

Skogen, M.D., and Moll, A., 2005. Importance of ocean circulation in ecological modelling: An example from the North Sea. Journal of Marine Systems, 57(3–4): 289–300.

Annex 7: Action Items 2006/2007

Item 1: Review existing operational data flow from sustainable observations and models and report on activities relevant for the work of WGPBI. Hans Dahlin and Cisco Werner.

Item 2: WKAMF: Complete MEPS issue. North, Gallego, Petitgas

Item 3: WKAMF: Draft of manual of best practices for next meeting. North Gallego Petitgas

Item 5: Develop a GOOS WG & WGPBI strategy. This was a recommendation of the WG. Follow up by Dahlin, Svendsen.

Item 6: Invite several speakers for a ½ day discussion on biodiversity inspired ecosystem models for the 2007 meeting. Hannah, Bruggeman.

Item 7: Assess the state of the art in the study of small scale feeding processes (with particular ref to zooplankton & Fish larvae) and make recommendations for model parameterisation. Uffe Thygesen. Possibly resource people. B. MacKenzie, A. Visser, H. Browman, G. Pfaffenhoffer.

Item 8: An important issue that arose in the general discussion was that it would be good to have some plankton specialists joining the group "to keep the modellers on the right track". Of particular interest to WGPBI are improved parameterizations of processes related to primary production. Names that came up were P. Gentien, L. Naustvoll, and J. Adolff. Einar Svendsen will contact Lars Naustvoll.

Item 9: Approach Grimm to present IBM state of the art modelling to the group. G.Huse

Item 10: Report on Conferences of interest to PBI, e.i., Euroceans Symposium on Ecosystem model Parameterisation, ICES/PICES young scientist conference, BASIN inititative.

Item 11: Develop a ASC SS for 2008 to address the state of the art and issues regarding model validation. Werner and St. John.

Item 12: Revive the Numerical Experimentation SubGroup

Item 13: Set up the PBI model inventory page so that people can submit suggestions for models/urls to add. North

Item 14: At 2007 meeting consider the following ToR for 2008, 'Review the state of the art with respect to the use of hydrodynamic models to predict optimal habitats' Possible project members. St. John, North, Huse, Hannah.

Item 15: At 2007 meeting consider the following two ToRs for 2008: 1) Continue to investigate (pre)operational applications of PBI models with special focus on the availability of its products; 2) Review, by using recent inventories, the access to operationally produced data that may be used for the development and validation of PBI models.

Item 16: The work of WKIMS should be carried on. WKIMS proposed the following ToR: Review progress in the estimation of meso-scale indices of oceanographic features and evaluate the reliability of the indices for their use in explaining fish distribution patterns. This requires a volunteer to pursue the work and report on it.

Annex 8: WGPBI activities

YEAR	EVENT
2004	Workshop on '**Future Directions for Modelling Physical Biological Interactions.**', chairs Peters and Hannah (Barcelona, March 2004). WGPBI meeting (Barcelona, March 2004). Theme Session at ICES ASC on **Physical-Biological Interactions: Experiments, Models and Observations** (September 2004, Vigo Spain). WG web page is located at www.icm.csic.es/bio/projects/wgpbi/wgpbi.htm and maintained by Cesc Peters.
2005	Theme Session at ICES ASC on **'Connecting Physical-Biological Interactions to Recruitment Variability, Ecosystem Dynamics, and the Management of Exploited Stocks'** with convenors North, St. John, and Gallego. Joint with WGRP. First meeting the Numerical Experimentation Subgroup (Hamburg, 6 April 2005). First meeting of the Larval Fish Group (Hamburg, 6 April 2005). WGPBI meeting (Hamburg, April 2005). Draft review of nutrient load reduction experiments. See Section 5 of 2005 Report. Report on the interannual variability comparison is now published as Skogen, M.D. and Moll, A., 2005. **Importance of ocean circulation in ecological modelling: An example from the North Sea**. Journal of Marine Systems, 57(3-4):289-300. Draft manuscript of modelling techniques for larval fish. T. Miller. What is current status?
2006	Workshop on '**Advancements in modelling physical-biological interactions in the early-life history of fish: recommended practices and future directions larval fish modelling**.' 3–5 April 2006 in Nantes France. Co-chairs: A. Gallego, E. North, P. Petitgas. WGPBI meeting 6–7 April 2006 in Nantes France. NESG meeting on 5 April 2006 in Nantes France. Database on effects of turbulence on planktonic organisms. F. Peters. What is current status? Peters, F., and C.G. Hannah (editors). 2006. **Special Issue on Future Directions in Modelling Physical-Biological Interactions**. J. Marine Systems. In press. Theme Session at the ICES ASC on '**Harmful Algae Bloom Dynamics; Validation of model predictions (possibilities and limitations) and status on coupled physical-biological process knowledge**'. Joint with WGHABD. Co-convenor T. Stipa Theme session at ICES ASC on '**Operational Oceanography**' (joint with PICES). Co-convenor: G. Han. Workshop on '**Indices of Meso-scale Structures in ICES waters**', 22-24 Feb,2006 in Nantes France. Joint with ICES SGRESP (Study Group on Regional Scale Ecology of Small Pelagics). Co-chair: C. Schrum Synthesis of progress on zooplankton modelling in German GLOBEC. T. Neumann and A. Moll Invite Geir Huse to give talk at WGPBI 2006 on zooplankton IBMs. M. Skogen. Radach, G. and Moll, A., 2006. **Review of three-dimensional ecological modelling related to the North Sea shelf system - Part 2: Model validation and data needs**. Oceanography and Marine Biology; an Annual Review, Vol. 44:in press. WGPBI "Inventory of Operational and Preoperational Models" at http://northweb.hpl.umces.edu/WGPBI/WGPBI_links.htm. WKAMF Participants Web Page at http://northweb.hpl.umces.edu/wkamf/home.htm

YEAR	EVENT
2007	WGPBI Meeting. Bergen Norway, March 2007. Theme session on PBI – Peer reviewed publication from larval fish workshop. Gallego, North, Petitpas Draft of manual of best practices for larval fish modelling. Gallego, North, Petitpas Good ideas for next generation of zooplankton modules in PBI models. Non-mass state variables and stage resolved, etc. All Workshop on ‘Parameterizing Ecosystem Models.’ Organized as part of EurOceans. St. John Review of temperature dependence of maximum growth rates for phytoplankton. St. John and Hannah
2008	Update WGPBI Inventory of Operational and Preoperational Models ICES ASC Theme Sessions
2009	
2010	

Annex 9: Draft ICES ASC Theme Session proposals

1) Linking oceanographic physical features with biological production and fish habitat potentials

This theme session is intended to review the state of the art and examine future directions in linking biological processes to physical features through mechanistic, stochastic or behavioural processes. Inductive as well as deductive approaches will be considered. Physical biological interactions occur at all scales, but the session will emphasise the consequences at the meso-scale of these interactions. The session will create an opportunity to scrutinise physical forcing effects all along the food web from plankton to the fish.

The theme session would be the opportunity to make a synthesis of works conducted in ICES groups WGPBI, WKAMF, WGRP, SGRESP, SGBEM, GLOBEC/SPACC and PICES. Endorsement by EUROCEANS and GLOBEC will be seeked.

Co-Chairs (to be confirmed): Charles Hannah (Canada), Pierre Petitgas (France), Corina Schrum (Norway).

2) Biodiversity inspired models for plankton ecosystem dynamics

Unifying biological principles, such as thermodynamic considerations and body size scaling, can offer the potential to derive ecosystem models for plankton dynamics that are unified models for wide ranges of marine species. One motivation for these new approaches is that traditional ecosystem models are based on extensions of single species models and require detailed quantitative knowledge of all relevant species. The process seems endless as ecologists and physiologists uncover relevant species and processes at rates that far exceed those at which high-quality quantitative knowledge on species becomes available. This theme session will provide a forum for discussion of the strengths and weaknesses of alternative approaches to ecosystem modelling with a focus on the capability to generate reliable quantitative predictions of biological variables.

3) Develop an ASC TS for 2008 to address the state of the art and issues regarding model validation. Werner and St. John.

Annex 10: Survey of current operational and pre-operational PBI models and their applications

(Action Item 12 by Stephan Dick, Elizabeth North, Morten Skogen and Trisha Amundrud)

An inventory of operational and pre-operational marine and estuarine 3D hydrodynamic and coupled bio-physical models had been carried out. An important criterion for the selection of models was that hindcast, nowcast and/or forecast data should be available on the internet. Although several colleagues who had been contacted by e-mail sent their contributions and web page URLs for the inventory, the compiled inventory is far from being complete. What was presented at the WG meeting in Nantes were examples of different PBI models with applications on the internet including short descriptions of programs, models, available output as well as information on model developers, funding and web URLs. The survey was only be carried out for Europe and the USA. In total, 40 web URLs had been compiled mostly presenting results of physical models. A webpage with the URL links was developed to help communicate survey results to the ICES community. It is entitled “WGPBI Inventory of Operational and Preoperational Models”

(http://northweb.hpl.umces.edu/WGPBI/WGPBI_links.htm).

Some examples of coupled physical-biological models and applications are described below.

1 Europe

1.1 Mediterranean Sea

In the Mediterranean Sea the EU project MFSTEP (Mediterranean Forecasting System Toward Environmental Prediction) as well as the MOON (Mediterranean Operational Oceanography Network) aim to further develop an operational forecasting system for the Mediterranean. Different regional and local 3D hydrodynamic circulation and dispersion models had been developed. Operational output covers mostly forecasts of water levels, currents, waves, salinity and temperature.

1.2 North West Shelf Sea and Baltic Sea

In the frame of NOOS (North West Shelf Operational Oceanographic System) and BOOS (Baltic Operational Oceanographic System) several 3D hydrodynamic circulation models as well as some biochemical models are being operated in the North West Shelf Sea and Baltic Sea. Output on the internet is mostly from (physical) 3D hydrodynamic circulation models, but also web pages with biochemical variables are available.

1.2.1 MRCS model of Met Office, POL, PML (UK)

The MRCS (Medium-Resolution Continental Shelf) model is a coupled hydrodynamic-ecosystem model for the North West European Shelf Sea, where the hydrodynamics are supplied by the Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS) developed at Proudman Oceanographic Laboratory (POL) and the ecosystem component (ERSEM) is supplied by Plymouth Marine Laboratory (PML). Operational output consists of near-real time maps of temperature, salinity, chlorophyll, zooplankton biomass and net primary production.

Web page URL: http://www.metoffice.gov.uk/research/ncof/mrcs/

1.2.2 Operational ecosystem model for the Baltic Sea (BalEco)

The Baltic Sea is frequently burdened by harmful algae in summertime. In order to better predict both the harmful algae and the ecological state of the Baltic Sea in general, an ecosystem model has been operationalised in the Finnish Institute of Marine Research in 2003. The MIT GCM finite volume model is forced with ECMWF and FMI weather forecasts as well as climatological freshwater and nutrient discharge. Operational output include real time state 3D estimates and forecasts of the ecological status of the Baltic Sea (nutrient concentrations, diatoms, flagellates, 2 cyanobacteria)

Web page URL: http://www.fimr.fi/en/itamerikanta/itamerinyt/ekomallit.html

1.2.3 MONCOZE – MOnitoring the Norwegian COastal Zone Environment

MONCOZE (Monitoring the Norwegian Coastal Zone Environment) is a development project for the North Sea and Skagerrak that aims to develop, test and demonstrate a pilot system for monitoring and prediction of the Norwegian marine coastal environment with particular focus on dominant physical and coupled physical-biochemical interactive processes. It represents a collaboration between Nansen Environmental and Remote Sensing Centre (NERSC), Institute of Marine Research (IMR) and met.no. The finite difference model MI-POM (based on the Princeton Ocean Model) is forced with an operational weather forecast model run at met.no using climatological lateral open boundary conditions and climatological freshwater run-off. The biochemical part includes two types of phytoplankton, three nutrients, oxygen and dead organic matter. Operational output are real time maps and seven days forecast of modelled currents, hydrography, phytoplankton and nutrients together with satellite images and in-situ observations.

Web page URL: http://moncoze.met.no/

1.2.4 The Water Forecast (DHI)

The Water Forecast of the Danish Hydrological Institute (DHI) provides tailor-made forecasts for different user groups in the Baltic, Danish Waters and the North Sea like fisherman, marine farmers, environmental authorities, yachtsman and others. The Water Forecast is produced by three models: a hydrodynamic model, a eutrophication model and a wave model. Operational output are five days forecast of modelled water level and currents, waves and swell, salinity and temperature, environmental indicators like oxygen and chlorophyll_a, winds and air-pressure. The users have to subscribe to the services.

Web page URL: http://www.waterforecast.com/

2 North America

2.1 USA

In the USA there are many physical 3D hydrodynamic circulation models as well as some biochemical models with operational applications on the internet.

2.1.4.1 Mapping Sea Nettles in the Chesapeake Bay

Sea nettles, *Chrysaora quinquecirrha*, seasonally infest the Chesapeake Bay and affect many activities on the Bay. Knowing where and when to expect this biotic nuisance may help to alleviate this problem, and help estimate their impact on food webs. Maps of probable sea nettle presence are created by identifying locations where the current environmental conditions are favourable to sea nettles. This is accomplished using data derived from hydrodynamic computer models and NOAA satellites. The finite element model QUODDY is used forced with existing conditions such as observed freshwater inflows, winds and water levels. Temperature and salinity predictions are combined with known temperature/salinity tolerances of sea nettles to predict sea nettle distribution. Operational output are near-real time maps of probability of encountering sea nettles in the Bay.

Web page URL: http://coastwatch.noaa.gov/seanettles/

2.1.4.2 Mapping Harmful Algal Blooms in the Chesapeake Bay

Various noxious and toxic algal blooms afflict the Chesapeake Bay, posing threats to human health and natural resources. Knowing where and when to expect these biotic nuisances may help mitigate their effects. The goal of this regional study is to predict the likelihood of blooms of several harmful algal bloom (HAB) species in Chesapeake Bay and its tidal tributaries. A first target species is the dinoflagellate *Karlodinium micrum*. *K. micrum* is seasonally abundant and has contributed to several fish kills in the bay. Numerical salinity predictions of the QUODDY finite element model, satellite-derived sea-surface temperature, and the salinity/temperature preferences of *K. micrum* are used to predict their abundance at low (0–10 cells/ml), medium (10–2000 cells/ml), and high (greater than 2000 cells/ml) concentrations. Near-real time maps of likely abundance of *Karlodinium micrum* are presented on the internet.

Web page URL: http://coastwatch.noaa.gov/cbay_hab/

2.1.4.3 Near-real time depiction of the California Current System

For the depiction of the California Current System the regional NCOM model NCOM-CCS with an embedded ecosystem model is used. NCOM assimilates daily MCSST surface temperature values and synthetic profiles of temperature and salinity obtained from the MODAS satellite product. The 1/8° global NCOM is run daily at the Naval Oceanographic Office (NAVOCEANO) with atmospheric forcing from the Navy Operational Global Atmospheric Prediction System (NOGAPS) and assimilation of SST and synthetic temperature and salinity profiles via the MODAS climatology based on input from the operational 1/16° NLOM SSH and 1/8° MODAS 2D SST nowcasts. Operational output consists of archived and near-real time data of modelled SST, SSH, chlorophyll, currents, and MODIS AQUA satellite products.

Web page URL: http://www7320.nrlssc.navy.mil/ccsnrt/

2.1.4.4 Nested Interdisciplinary Models for the Gulf of Alaska

Archived data of nested models for the coastal Gulf of Alaska are presented for the state variables dissolved iron, nitrate, phytoplankton, salinity, temperature, current velocity. Data had been computed by the Nutrient-Phytoplankton-Zooplankton (NPZ) model in ROMS Coastal Gulf of Alaska model nested within Northern Pacific and Northeast Pacific grids.

Web page URL:

http://www.pmel.noaa.gov/~dobbins/research.html

http://ferret.pmel.noaa.gov/FOCI/servlets/dataset

Summary

Many web pages of physical operational models and applications could be found on the internet. However, there exist relatively few examples of bio-physical coupled models and applications. A few examples present synthesis of in-situ measurements, remote sensing and forecast data. Most PBI web pages show model results for lower trophic levels. The typical model output consists of (near) real time maps of physical parameters together with nutrients and phytoplankton (chlorophyll) distribution. A few models show applications for certain species (*Chrysaora quinquecirrha, Karlodinium micrum ...).* In some countries operational biochemical models are being developed at the moment.

Recommendations

It is recommended to repeat the survey of operational and pre-operational PBI models and their applications within two years in order to update the description of available models and products and to investigate the progress in development of operational PBI models. Also, it is recommended that the “WGPBI Inventory of Operational and Preoperational Models” webpage should be linked to the WGPBI webpage.

Annex 11: Identification of ideas for embedding PBI in operational models

Notes on the discussion of ideas for embedding PBI in operational models. Much of the material is taken from Einar Svendsen's presentation.

Why modelling?

Due to the dynamics and complexity of the marine ecosystems, and the challenge of quantifying human interference from large natural variability, this is only possible by extensive use of mathematical models in combination with observations.

The ecosystem approach

The ecosystem approach to marine ecosystem research and management advice (with respect to science) is to consider the most important driving forces on, and the processes within the ecosystems.

The driving forces are:

- Climate-physics (directly on all trophic levels and indirectly bottom-up through the lower trophic levelsæ
- Fisherman-fisheries management (top-down)æ
- Fertilization?
- Pollution?
- Introduction of new species?
- Habitat disturbance?

The operational 3D modelling possibilities (existing or within "short" term reach

Hindcast (50 year), nowcast and forecast (week (or 100 years)) of:

- Relevant physics – Circulation, temperature, salinity, turbulence;
- Phytoplankton – Concentration of functional groups (or specific (harmful) species), nutrients, detritus, oxygen, sedimentation, light;
- Zooplankton – Individual species (or functional group(s)? (IBM or Eulerian);
- Fish larvae – growth and distribution (and mortality?) (IBM);
- Fish migration – growth and distribution (overlap between species**).**

Ideas for operational indicators (time-series)

- Position of fronts;
- Extent and area of melting sea ice (if relevant);
- Area and volume of specific water masses;
- Upwelling indexes;
- Currents, temperature and turbulence;
- Particle and tracer distributions from given sites (spawning, oil production….);
- Fluxes of water masses and nutrients (though given sections);
- Timing (of peak spring bloom) and strength of primary prod.;
- Light in water column;
- Transport, growth and distribution of zoo-plankton;
- Transport, growth and distribution of selected fish larvae;
- Contaminant exposure on plankton and benthic ecosystems;

- Sedimentation (resuspension);
- Overlap between species (prey and predators).

Ecosystem approach

To improve and believe in statistical results, we first of all need realistic modelling of zooplankton (coupled to physics and primary production).

The next three figures show examples for the potential for dynamical models to make useful predictions for fisheries management. The examples are taken from Einar Svendsen's presentation on the Norwegian modelling system.

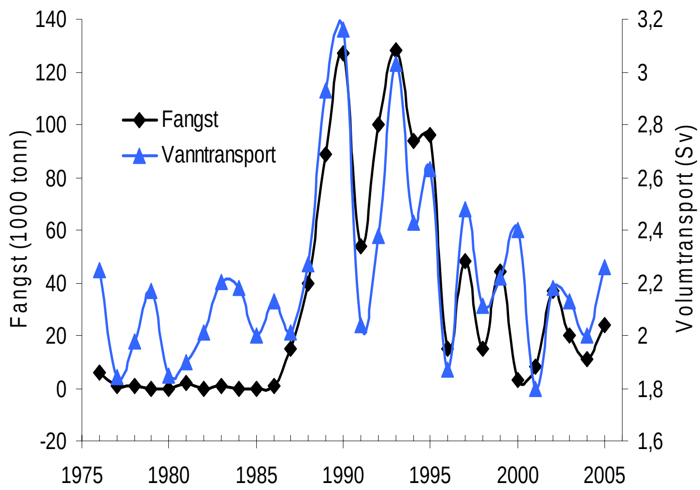
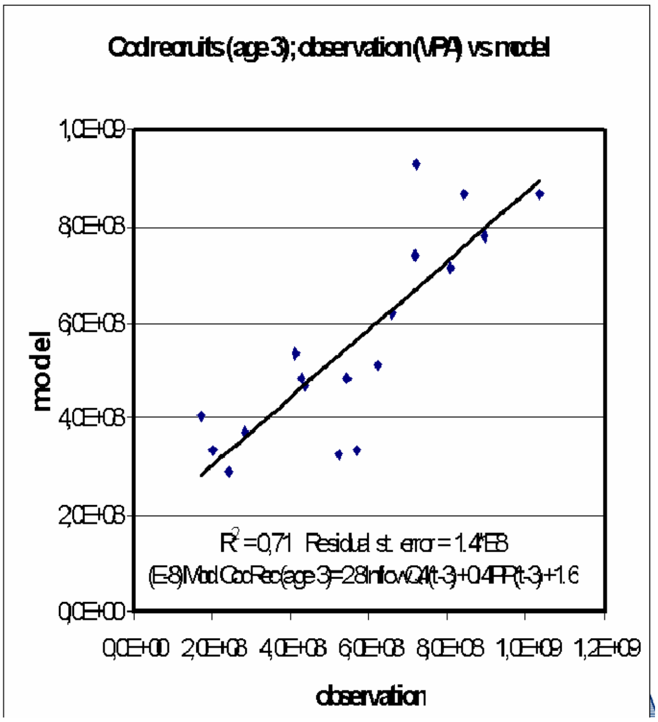


Figure A11.1: Predicting horse mackerel fishing from modeled volume transport.



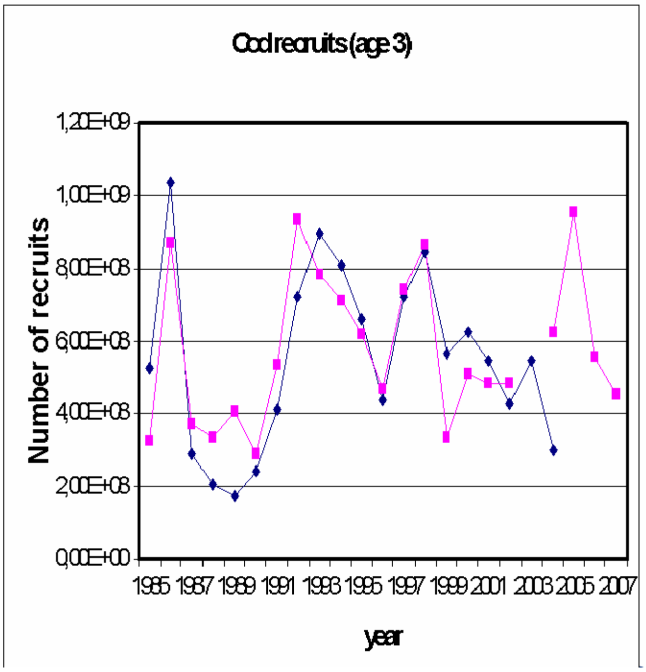


Figure A11.2: Predicting cod recruitment based on transport and primary production.

Annex 12: The influence of water dynamics on the distribution of 0-group herring in the Barents Sea

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Water circulation plays an important role in all processes taking place in the water environment and influences both directly and indirectly the oceanographic, meteorological and biological conditions of seas, as well as human activity on exploitation of marine resources. Physical processes, including water dynamics, determine not only the areas of young herring dwelling, but the differences in its growth rate and time of maturity coming. This leads to the large interannual variations of the commercial stock recruitment value (Seliverstov and Penin, 1969).

So in this paper an attempt was made to study the influence of the Barents Sea circulation on the distribution and abundance of 0-group herring with the purpose of searching for quantitative relations between them using the hydrodynamic model (Trofimov, 2000). For that, the wind-driven and general circulation of the Barents Sea, as well as volume fluxes (both wind-driven and total) through the sections crossing the main currents (Figure A12.1) were calculated for every month from 1983 to 2004.

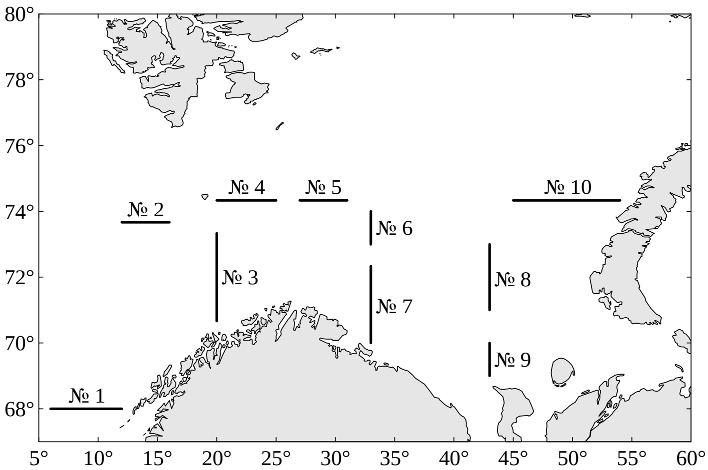

Figure A12.1: The model domain and position of sections selected for calculation of fluxes.

Numbers of sections and names of currents crossed by them: **1** - the Norwegian Current (**Nc**), **2** - the Spitsbergen Current (**Sc**), **3** - the North Cape Current (**NCc**), **4** - the Bear Island Current (**Bc**), **5** - the Northern Branch of the North Cape Current (**NbNCc**), **6** - the Central Branch of the North Cape Current (**CbNCc**), **7** - the Murman Current (**Mc**), **8** - the Novaya Zemlya Current (**NZc**), **9** - the Kanin Current (**Kc**), **10** - the Western, Eastern and Coastal Branches of the Novaya Zemlya Current (**WECbNZc**).

Then the correlation matrices containing the coefficients of pair correlation between indices of 0-group herring abundance and fluxes calculated with different periods of averaging (from 1 to 12 months) were built for each section. As a result, predictors for constructing regression equations were found. At that, time and place of spawning were taken into account, as well as the periods, when larvae and fries were transferred through the selected sections. Besides, it was barred to use for the same regression equation such predictors which had significant relations between each other.

For 1983–1998 the relations between the fluxes (both wind-driven and total) and such parameters describing 0-group herring distribution and abundance as an area index of abundance (Ind), an area of concentrations (S), and the northern (Lat) and eastern (Lon) borders of distribution were considered. Roman numerals in the following equations show the period of averaging of the fluxes.

Ind=940.9-670.4*NCcVI-VII+3017.1*KcVIII, (total fluxes) R^2=0.61

Ind=149.7+8413.1*ScVI-VII+2315.4*NCcVIII, (wind-driven fluxes) R^2=0.52

S=25.5+68.2*ScVIII-130.4*NCcVI-VII+111.6*McVIII+508.6*KcVIII,
(total fluxes) R^2=0.84

S=87.6+1130.2*ScVI-VII+1142.6*NCcVIII-4864.9*CbNCcVIII+1533.2*NZcVIII,
(wind-driven fluxes) R2=0.58

Lat=1/(0.0112+0.002/ScVIII), (total fluxes) R^2=0.64

Lon=17.5+167.9*KcVIII, (total fluxes) R^2=0.50

Lon=42.1+231.3*NCcV-VIII. (wind-driven fluxes) R^2=0.71

For a larger period (1983–2004) the relations between the total fluxes and indices of 0-group herring abundance (an area index of abundance (Ind) and an index of absolute abundance (Abund)) were considered. It was decided to use only the total fluxes, because they describe the variability of the indices of 0-group herring abundance better than the wind-driven fluxes.

Ind=3028.7-276.7*ScIII-IV-2073.8*NbNCcVI-VII-355.2*NZcVIII,
(total fluxes) R2=0.60

Abund=3041670+1089170*BcVII-1363750*NbNCcVI-VII,
(total fluxes) R2=0.54

All coefficients in the presented equations are statistically significant. It was proved with the use of Student's test and a level of significance. The acceptable values of Fisher's test and a significance level point out the adequacy of these regression models.

Analyzing the obtained equations one can assume that when the fluxes, that is currents, decrease, drifting larvae and fries of fish adapt better to the varying environmental conditions and are transferred to the areas with unfavourable survival conditions to a lesser extent.

The regression equations obtained in the paper can be probably used for restoration of missing area indices of 0-group herring abundance.

In conclusion, the test predictions of the indices of 0-group herring abundance were prepared for September 2005 on the data available in the PINRO database by 1 August 2005 (Table A12.1). Both predictions came true.

Table A12.1: Test predictions of 0-group herring abundance indices.

INDEX	FACTUAL VALUE (ANON., 2005)	PREDICTED VALUE	DIFFERENCE BETWEEN FACTUAL AND PREDICTED VALUES	ALLOWABLE ERROR, ±0.674Σ
Area index of abundance	205	299	−94	±118
Index of absolute abundance	125 719	104 303	21 416	±154 107

This work is intended to be used within the framework of a comprehensive approach to studying of herring abundance formation. It was also noted that besides water dynamics it is necessary to use additional parameters connected with the species biology (a speed of larvae ascent, a spawning stock level, population fecundity etc.) in order to describe correctly variability of 0-group fish abundance in the Barents Sea.

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